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# Grazing systems, pasture size, and cattle grazing behavior, distribution and gains

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## Abstract

**Reduced pasture size and distance to water may be responsible for the alleged benefits of intensive time-controlled rotation grazing systems. We compared cattle gains, activity, distance traveled, and forage utilization on a time-controlled rotation system with eight 24-ha pastures, on two 24-ha pastures grazed continuously (season-long), and on a 207-ha pasture grazed continuously, all stocked at the same rate. Utilization on the 207-ha pasture, but not on the 24-ha pastures, declined with distance from water. At distances greater than 3 km from water in the 207-ha pasture, utilization was significantly less than on adjacent 24-ha pastures, at distances of 1.0 to 1.6 km from water. Cows on the 207-ha pasture travelled farther (6.1 km/day) than cows on the 24-ha rotation pastures (4.2 km/day), which travelled farther than cows on the 24-ha continuously grazed pastures (3.2 km/day). Grazing system, range site, slope, and weather had minimal effects on cow activity patterns. Gains of cows and calves were less on the 207-ha pasture (0.24 and 0.77 kg/day, respectively) than on the 24-ha rotation pastures or 24-ha continuously grazed pastures (0.42 and 0.89 kg/da, respectively), with no differences between the latter. Calculated "hoof action" on the rotation pastures was less than that demonstrated to increase seed burial and seedling emergence. Intensive rotation grazing systems are unlikely to benefit animal performance unless they reduce pasture size and distance to water below previous levels, decreasing travel distance and increasing uniformity of grazing.**

**Key Words: continuous grazing, grazing time, native range, season-long grazing, short-duration rotation grazing, time-controlled grazing, travel distance**

Intensive time-controlled rotation grazing systems are characterized by multiple pastures, high stocking density, grazing periods short enough that regrowth is not grazed within the period, and lengths of grazing and rest periods that increase in length as forage growth rate decreases. Such systems have been called short-duration grazing (Savory 1978, Savory and Parsons 1980), Savory Grazing Method (SGM) or Holistic Resource Management (HRM) (Savory 1983), and planned grazing (Savory 1988). We have called the method time-controlled grazing (Hart et al. 1986) or short-duration rotation grazing (Hart et al. 1988a). The time-controlled rotation grazing used in this study will be called simply rotation grazing, since no other form of rotation grazing was examined.

Benefits claimed for time-controlled rotation grazing, in addition to doubled stocking rates, are those derived from concentrating animals in a small pasture to produce "hoof action". Hoof action supposedly breaks up surface crusts; aids water infiltration; incorporates litter and manure into the soil, speeding nutrient cycling; and buries seeds to help new plants become established (Savory 1983). Research has seldom confirmed the claimed bene-

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fits of short-duration rotation grazing to animals, plants and soil (Bryant et al. 1989; Dormaar et al. 1989; Gillen et al. 1991; Hart et al. 1988a; Heitschmidt et al. 1982, 1985, and 1987; Taylor 1989; Weltz and Wood 1986). However, Hart et al. (1988a) confirmed that stocking rates can profitably be increased substantially above "government-prescribed stocking rates", although doubling them seems unduly risky (Hart 1991). Laycock (1983) and Lehnert (1985) pointed out that improved management is more important than rotation in achieving the benefits of grazing systems. Furthermore, subdividing large pastures to implement a rotation system may reduce distances to water and provide more uniform use of forage.

With these possibilities in mind, we designed a grazing study to separate the effects of time-controlled rotation from those of pasture size and distance to water, under uniformly good management. Our hypotheses were that (1) at the same stocking rate, cattle gains and activity and uniformity of grazing would be similar on rotation and continuously grazed pastures of similar size and shape with livestock water in similar locations, and (2) grazing would be less uniform and cattle would travel farther and gain less in a large continuously grazed pasture than in smaller rotation or continuously grazed pastures.

## Materials and Methods

### Pasture Layout

Layout of the experimental pastures is shown in Figure 1. The 2 continuous small pastures (CS1 and CS2) each covered 24 ha, except in 1986 and 1987 when the east fence of CS1 ran south to north rather than southwest to northeast and that pasture covered 34.4 ha. The continuous large pasture (CL) covered 207 ha, and was deliberately designed to produce a gradient of cattle distribution and forage utilization and to estimate the effects of these gradients on cattle gains. Each pasture contained a water source at one end. Maximum distances to water were 5.0 km on the continuous large pastures and 1.0 to 1.6 km on the rotation and continuous small pastures.

### Forage Production and Utilization

Forage production and utilization estimates on Figure 1 indicate locations of 1.2 × 1.2-m exclosures 1986–1990. Exclosures at the ends farthest from water of the rotation pastures and of continuous small pasture 2 were paired with exclosures across the fence in the continuous large pasture. In 1988–1990, additional exclosures were located near water in rotation paddocks 1, 3, 5, and 7 and in CL, comparable to the exclosures near water in CS1 and 2.

Peak standing crop was estimated in each exclosure in late July or early August each year. Production was estimated on two 0.18-$m^2$ quadrats within each exclosure with a capacitance meter. In every second or third exclosure, forage from 1 quadrat was clipped to ground level, dried, and weighed.

After cattle were removed from the pastures, residual herbage was estimated. Five capacitance meter readings 4 paces apart were taken, beginning at a random distance between 10 and 20 paces from each exclosure and walking in a random direction. One quadrat near every 2 or 3 exclosures was clipped, dried, and weighed. Meter readings and weights from the clipped quadrats were used to calculate a calibration equation. These equations were linear with correlation coefficients ($r$) of 0.86 to 0.93; n = 8 to 14.

Peak standing crop was the mean of estimates from the 2 quadrats in each exclosure or, in the case of paired exclosures, from the 4 quadrats in both exclosures. Utilization was calculated as (peak standing crop-residual)/peak standing crop × 100, from each of the 5 estimates of residual herbage near each exclosure.

To estimate small-scale heterogeneity of utilization, in 1987 2 pairs of transects were established in each small continuous pasture and in rotation pastures 4 and 5. Four pairs of transects were established in the large continuous pasture. In the small continuous pastures, 1 pair was placed 100 to 200 m from water and the other 400 to 700 m from water. Corresponding distances in the rotation pastures were 200 to 300 m and 700 to 1,000 m. In the large continuous pasture, transect pairs were 700, 900, 2,600, and 3,200 m from water. Transects consisted of 128 segments, each 8 cm long, for a total length of 10.24 m. Paired transects were parallel and about 20 m apart.

In July and September of 1987, aerial cover, fraction of segment showing grazing, and utilization was estimated for each segment of each transect. Utilization was scored as none, no herbage removed; light, up to 25% removed; moderate, 26 to 50% removed; heavy, 51 to 85% removed; and over-utilized, over 85% utilization. A grazed patch consisted of 1 or more grazed segments with ungrazed segment(s) on each side.

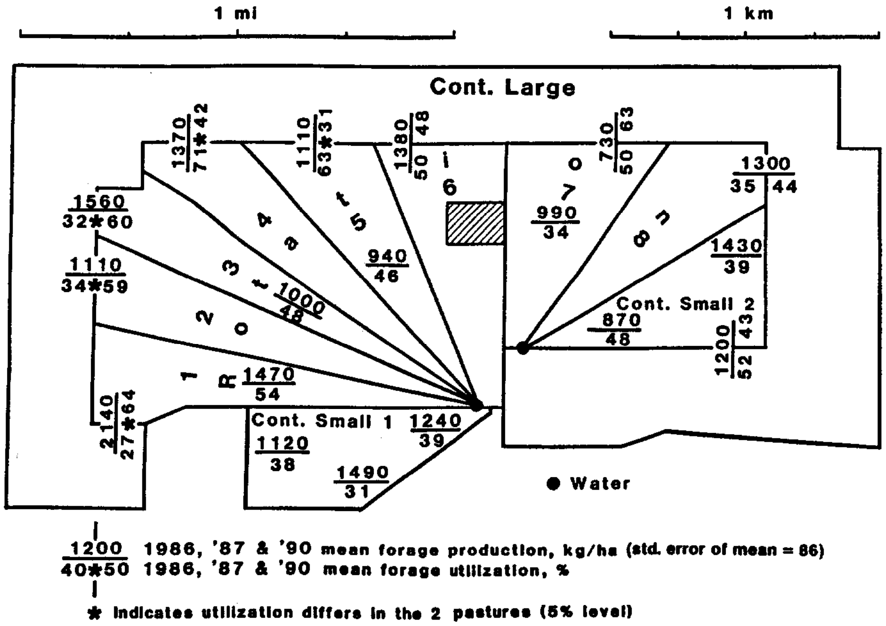


**Fig. 1. Pasture layout, location of exclosures 1986–1990, and forage production and utilization.**

**Table 1. Forage production, days grazed, stocking rate, and grazing pressure on large and small continuously-grazed and small rotationally grazed pastures.**

| Year | Forage mean (std error) | Days grazed | Pasture Name | Pasture Size | Pairs (1 AU) | Dry cows (0.9 AU) | Heifers (0.75 AU) | Animal units | AU days /ha | AU days /Mg |
|---|---|---|---|---|---|---|---|---|---|---|
| (kg/ha) | | | | (ha) | (No.) | (No.) | (No.) | | | |
| 1986 | 960 | 124 | Continuous Large | 207.3 | 36 | 6 | 13 | 51.15 | 30.6 | 31.9 |
| | (82) | | Continuous Small 1 | 31.8 | 7 | 0 | 3 | 9.25 | 36.1 | 37.6 |
| | | | Continuous Small 2 | 24.3 | 6 | 0 | 0 | 6.00 | 30.6 | 31.9 |
| | | | Rotation | 194.3 | 40 | 5 | 11 | 53.25 | 34.0 | 35.4 |
| 1987 | 1190 | 148 | Continuous Large | 207.3 | 26 | 16 | 16 | 52.40 | 37.4 | 31.4 |
| | (131) | | Continuous Small 1 | 31.8 | 7 | 1 | 3 | 10.15 | 47.2 | 39.7 |
| | | | Continuous Small 2 | 24.3 | 4 | 1 | 3 | 7.15 | 43.5 | 36.6 |
| | | | Rotation | 194.3 | 23 | 19 | 14 | 50.60 | 38.5 | 32.4 |
| 1988 | 1150 | 141 | Continuous Large | 207.3 | 19 | 27 | 10 | 50.80 | 34.6 | 30.0 |
| | (118) | | Continuous Small 1 | 24.3 | 3 | 3 | 0 | 5.70 | 33.1 | 28.8 |
| | | | Continuous Small 2 | 24.3 | 3 | 0 | 5.70 | 33.1 | 28.8 | |
| | | | Rotation | 194.3 | 19 | 24 | 7 | 45.85 | 33.3 | 28.9 |
| 1989 | 530 | 77 | Continuous Large | 207.3 | 32 | 0 | 3 | 34.25 | 12.7 | 24.0 |
| | (62) | | Continuous Small 1 | 24.3 | 3 | 0 | 1 | 3.75 | 11.9 | 22.4 |
| | | | Continuous Small 2 | 24.3 | 3 | 0 | 1 | 3.75 | 11.9 | 22.4 |
| | | | Rotation | 194.3 | 27 | 1 | 5 | 31.65 | 12.5 | 23.7 |
| 1990 | 1620 | 149 | Continuous Large | 207.3 | 30 | 2 | 19 | 46.05 | 33.1 | 20.4 |
| | (199) | | Continuous Small 1 | 24.3 | 3 | 1 | 1 | 4.65 | 28.5 | 17.6 |
| | | | Continuous Small 2 | 24.3 | 4 | 0 | 1 | 4.75 | 29.1 | 18.0 |
| | | | Rotation | 194.3 | 27 | 5 | 10 | 39.00 | 29.9 | 18.5 |

### Livestock Behavior and Gains

Pastures were stocked each spring with cow-calf pairs and, in most cases, dry cows and yearling heifers (Table 1). We tried to maintain the same stocking rates in all pastures, but this was not always possible with the available livestock and pasture sizes. If an animal became ill or died, it was replaced if a similar replacement was available, except in 1987. Cattle were weighed every 4 weeks, after feed and water were withheld overnight.

In 1989 and 1990, 6 nursing cows in the rotation herd, 6 in the herd on CL, and 3 in each herd on CS1 and CS2 were fitted with plastic neck chains. Each chain in a herd was a different color. On selected days, herds were observed from dawn to dusk and the activity and location (on a 100-m grid) of chained cows was recorded at 15-min intervals. The rotation herd was observed in pastures R4 and R5. Occasionally a cow would lose her neck chain during or just before an observation day so it was not possible to observe the planned number of cows on every day.

Distance travelled was calculated by summing straight line distances between centers of grid squares occupied at successive observations. This provides a more reliable estimate than use of pedometers (Anderson and Kothmann 1980, Walker et al. 1985), which essentially count steps and multiply by a constant. While stride length may be relatively constant during non-grazing travel, it varies greatly during grazing (Test 1984).

Grazing events per hectare were calculated as total number of observations per ha/number of cow-days observed × number of animal-days per pasture per year. Each event was considered to represent 15 minutes of activity, so hours of grazing was calculated as events/4. Percent of time spent grazing, nursing, resting, or travelling was calculated as observations in that activity/total number of observations × 100.

### Data Analysis

Average daily gain of nursing cows, calves, dry cows, and heifers was subjected to analysis of variance in each year, with animals as experimental units (Conniffee 1976). Distance travelled and percent of time spent in each activity were similarly analysed. Because no activity ever occupied 0 or 100% of the day, data were approximately normally distributed in spite of being percentage data. Differences were considered significant if probability of Type I error was less than 0.05. Analysis indicated no significant difference in gain of any class of cattle or in activity of nursing cows between CS1 and CS2, so data were pooled across these pastures. The same was true of rotation pastures R4 and R5.

Within each year, utilization was subjected to analysis of variance, with the 5 utilization estimates per exclosure treated as samples. Again, percentage data were normally distributed. The pooled sampling error mean square was used to test for differences between paired exclosures, for differences among exclosures within a pasture, and for differences among pastures. Mean utilization for 1986, 1987, and 1990 was analysed with years as main plots, exclosures as subplots, and utilization estimates as samples.

Utilization data for 1988 were eliminated from this analysis because herd composition was substantially different from that in other years. Distribution and forage utilization patterns of highly mobile dry cows are not the same as those of more sedentary nursing cows. No differences in use among pastures or locations within pastures were detected in 1988; mean use was 50%. Data from 1989 were eliminated because little forage was produced and cattle had to be removed when forage utilization reached only 17%.

Simple and multiple regression equations, using percent utilization or grazing time per hectare as the dependent variable and distance to water, percent slope and range site as independent variables, were calculated.

Grazed patches per transect, patch length, and segments overutilized as a percentage of all segments grazed were analyzed with each transect of a pair as samples within distances and within pastures. Heterogeneity chi-square was used to test variability in utilization among transects.

## Results and Discussion

### Cattle Activity

In 1989, cows in the continuous small pastures (CS1 and CS2) spent a smaller percentage of time grazing than cows in the continuous large pasture (CL; Table 2). No other differences in grazing time were observed. Cows spent about 93% of the time grazing and resting.

Inevitably, resting time was negatively correlated with grazing time. Cows on CS spent more time resting than cows on the rotation pastures (R4 and R5) or CL in 1989. Cows spent about 3% of the time nursing calves, with no differences among treatments in either year.

Table 2. Time spent in various activities by nursing cows on large or small continuously-grazed or small rotationally-grazed pastures.

| Year | Pasture | Grazing | Resting | Travelling | Nursing |
|---|---|---|---|---|---|
| | | % of time observed | | | |
| 1989 | Continuous Large | 60 a | 30 a | 6 a | 4 a |
| | Continuous Small | 51 b | 43 b | 3 b | 3 a |
| | Rotation | 57 ab | 37 b | 3 b | 3 a |
| 1990 | Continuous Large | 56 a | 35 a | 6 a | 3 a |
| | Continuous Small | 58 a | 37 a | 3 a | 3 a |
| | Rotation | 54 a | 40 a | 4 a | 3 a |

a,b Percentages within year and activity, followed by different letters, are different ($P \leq 0.05$).

Cows spent an average of 56% of daylight hours grazing, equivalent to 9.0 hr/day during the 16 hours of daylight at summer solstice in June and 7.8 hr/day during the 14 hours of daylight in late August and early September. Walker and Heitschmidt (1989) reported that cows grazed 11.3 hr/day in May and June and 9.5 hr/day in August and September. However these grazing times included night-time grazing, which was not observed in our study. Total grazing time did not differ among continuous grazing and rotational grazing in 14 or 42 paddocks. Hepworth et al. (1991) reported that steers grazed an average of 8.5 hr/day during daylight hours. In the third year of their study, steers at heavy stocking grazed longer under continuous than under rotation grazing; in no other case were differences found between systems.

Cows spent about twice as much time travelling on CL as on R or CS, but the difference was significant only in 1989. Cows travelled about 6.1, 3.2, and 4.2 km/day on CL, CS, and R, respectively (Table 3). They travelled farther on R than on CS, and about 70% farther on the 207-ha CL than on the 24-ha R or CS.

Table 3. Distance traveled by nursing cows on large or small continuously-grazed or small rotationally-grazed pastures.

| Type of travel | Pasture | 1989 | 1990 | Mean |
|---|---|---|---|---|
| | | km/day | | |
| Total | Continuous Large | 6.4 a | 5.8 a | 6.1 a |
| | Continuous Small | 3.2 c | 3.2 c | 3.2 c |
| | Rotation | 4.4 b | 4.0 b | 4.2 b |
| Grazing | Continuous Large | 4.0 a | 3.6 a | 3.8 a |
| | Continuous Small | 2.6 b | 2.8 b | 2.7 c |
| | Rotation | 3.2 ab | 2.9 b | 3.1 b |
| Non-grazing | Continuous Large | 2.4 a | 2.2 a | 2.3 a |
| | Continuous Small | 0.6 b | 0.4 b | 0.5 c |
| | Rotation | 1.2 ab | 1.1 ab | 1.2 b |

a,b Distances within type of travel and years or mean, followed by different letters, are different ($P \leq 0.05$).

Travel was divided into grazing and nongrazing travel. Nongrazing travel included travel to and from water or travel of over 100 m without stopping to graze; the latter contributed very little. Grazing travel was 3.8, 2.7, and 3.1 km/day on CL, CS, and R, respectively (Table 3), and was less in the small CS and R pastures than in the large CL pasture, with no difference between CS and R. Most of the differences in travel among systems occurred when the cows were not grazing. Nongrazing travel was 2.3, 0.5, and 1.2 km on CL, CS, and R; all differences were significant.

Walker and Heitschmidt (1989) reported that cows travelled 5.8 km/day in a 248-ha continuous pasture and 6.5 and 8.2 km/day in 27-ha and 10-ha rotation pastures, respectively. Pastures in this study were similar in size to ours, yet differences between sizes were small, probably because maximum distance to water varied only from 1.3 to 1.4 km among treatments, vs. 1.0 to 5.0 km in our study. Heifers travelled 5.5 km/day in 4-ha rotation pastures vs. 6.1 km/day in a 20-ha continuous pasture (Anderson and Kothmann 1980). Hepworth et al. (1991) estimated that steers travelled 2.7 km/day in pastures where maximum distance to water was 640 m vs. 1.9 km/day where distance was 240 m. Distance to water, not pasture size or grazing system, appears to be the major factor controlling distance travelled.

Nongrazing travel on R and CS was *positively* correlated with the number of times cows went to water; $r$ values were 0.76 and 0.78, respectively. On CL, nongrazing travel was *negatively* correlated with times at water; $r = -0.62$. As cows grazed farther from water on the large pasture, they went to water less often, regardless of weather. Fewer trips compensated for the greater distance to water.

Cows did not go to water at all on cool damp days such as 20 July 1990 (maximum temperature 14° C, 7 mm of rain), and usually stopped grazing when it was actually raining. No other relationships were detected between weather and time in activity or distance travelled, although Anderson and Kothmann (1980) found distance travelled was correlated with precipitation, temperature, and the ratio of water vapor to dry air in the atmosphere.

## Hoof Action

An estimate of "hoof action" can be calculated from travel distance and stocking density. Nongrazing travel contributed little to hoof action, because nearly all of it was done on established paths. Therefore our calculations were based on grazing travel.

Test (1984) spent many hours observing grazing cattle and concluded that, while length of stride varied greatly depending on what the animal was doing, average stride lengths of mature cows were about 45 and 90 cm, respectively, while grazing and travelling. Thus for each kilometer traveled by a cow while grazing, each leg took about 2,222 steps or approximately 9,000 steps for all 4 legs. Measurements of hoofprints showed an average area of about 100 $cm^2$, so about 90 $m^2$ was trampled for each kilometer traveled per animal. Heifers would take slightly shorter steps and therefore more steps per km, but hoofprints would be smaller so the same area per km traveled will be used.

Heaviest stocking on R occurred in 1987, with 56 cows and heifers on the system. With all 56 head in a single 24-ha pasture, each travelling 3.1 km/day while grazing, the maximum area trampled if no overlap occurred would be 15,624 $m^2$ or 1.56 ha. Some steps almost certainly overlapped but it is not possible to calculate how many. In a 144-day grazing season on an 8-pasture system, 18 days per pasture, the area trampled would be about 28 ha or 1.17 times the area of the pasture. Adding trampling by calves would slightly increase this figure, but allowing for overlap of hoofprints would decrease it. Dividing the area into more pastures, assuming that travel distance was unchanged, would not increase the total area trampled but would concentrate the effect in fewer days.

Trampling densities may influence seedling establishment. Under a 10-paddock intensive rotation grazing system, nearly all crested wheatgrass seedlings were destroyed by trampling (Salihi and Norton 1987). Zero, light, or heavy trampling, followed by rain, buried 20, 28, and 45% respectively of seeds of 4 grass species within the "biological limit" for emergence (Winkel et al. 1991). Differences between no and light trampling were not significant; differences between light and heavy trampling were significant in 2 of 8 year × species combinations. Heavy trampling increased seedling emergence of 1 of 4 grasses in a wet year, all 4 in a moderately wet year, and none of the 4 in a dry year (Winkel and Roundy 1991). Heavily trampled soils took up water faster than untrampled soils immediately after trampling, but took up less water later in the season (Roundy et al. 1992). Light trampling was approximately 10 hoofprints per $m^2$, or 0.1 of the area trampled as calculated by the method outlined above. The area affected by heavy trampling is

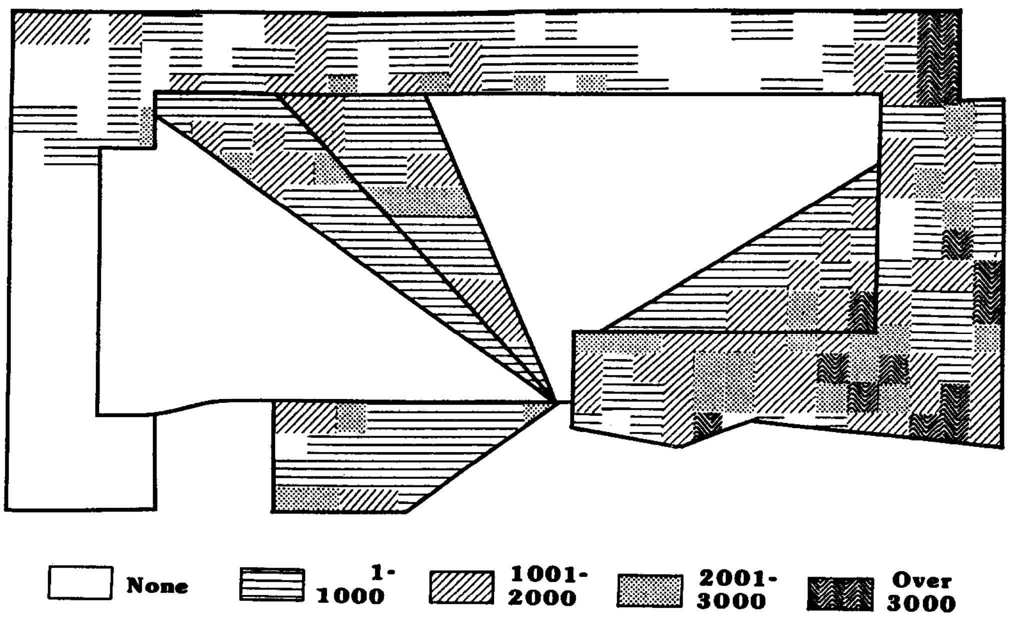


**Fig. 2. Cattle hours of grazing per hectare, 1990. Activity was estimated in pastures 4 and 5 of the rotation treatment, and in both small and the large pastures of the continuous grazing treatments.**

harder to calculate. Five cattle were herded inside a 6 × 6 m enclosure for 20 min. If they constantly walked at 6 km/hour, all 5 cattle travelled a total of 10 km and trampled an area of 900 $m^2$ or 25 times the area of the plot. Thus trampling at about 20 times the density observed in our study only sometimes increased emergence and only temporarily increased water infiltration. Abdel-Magid et al. (1987) and Taylor (1989) calculated that trampling at this density would reduce water infiltration and increase soil bulk density.

**Uniformity of Use**

Percent use (Fig. 1) did not differ significantly among locations within the 24-ha continuously grazed pastures (CS) or rotation paddocks (R). Use declined with distance from water in CL, the 207-ha continuously grazed pasture; Use = 0.60 – 0.0059 D, when D = distance to water in m; $r^2$ = 0.55. At distance greater than 3 km from water in CL, use was less than in adjacent rotation pastures with distances to water of 1.0 to 1.6 km. Webb (1931) noted that by the end of the 19th century, government publications stated that cattle should not walk more than 2 1/2 miles (4 km) to water. Nevertheless, some cattle producers are astonished to discover an increase in uniformity of use and livestock production when enormous pastures are subdivided and new water sources provided as part of a grazing system (Laycock 1983, Bryant et al. 1989, Taylor 1989). They credit the improvement to rotation grazing, not to reduced distances to water.

It should be emphasized that fencing to divide a larger pasture with a single pre-existing water source into a number of smaller pastures radiating out from that source does not reduce the distance to water on any part of that pasture, regardless of pasture size or location of the water source. On the other hand, providing new water sources can reduce the distance to water on large areas of the pasture without any pasture subdivision whatsoever. Everhart (1991) points out that locating water sources so pastures can be subdivided into smaller square rather than wedge-shaped pastures greatly reduces the amount of fence needed and more efficiently decreases the average distance to water. Walker and Heitschmidt (1986) found that dividing a pasture into 14 wedge-shaped pastures increased the number of cattle trails, and further dividing one of these pastures into 3 increased the number of trails even more.

At a finer scale along the paired transects, there were few differences among systems. In July, significantly more of the grazed segments were over-utilized under R (15%) than under CS (2%); CL was intermediate at 7%. By September, more grazed segments were overused under CS (46%) than under R (30%); CL was again intermediate at 37%. The rotation schedule was such that more animal-days of grazing had occurred on the R paddocks measured than on CL or CS in July; the reverse was true in September. By September all systems averaged 2.4 grazed patches per meter of transect, and average grazed patch length was 21 cm on R and CS and 17 cm on CL; differences were not significant.

Estimated cow-hours of grazing per hectare in 1990 (Fig. 2) also were related to D or distance to water in meters; Cow-hour/ha = 1726 – 0.35 D; $r^2$ = 0.17. No significant correlations between grazing time and slope or range site were detected, although cows appeared to spend more time grazing along the intermittent streams in R4, R5, and CL than in adjacent uplands. Senft et al. (1983, 1985) and Launchbaugh et al. (1990) found much greater differences in preference among sites, but vegetation also differed more among sites in their study. Our sites were quite similar, although loamy sites produced more total forage and blue grama (56% vs. 50% by weight) and less needleandthread (4% vs. 12%) than gravelly loamy sites, and supported somewhat different forb populations. However, forbs produced only 8% of total production (Hart and Samuel 1985).

DeYoung et al. (1988) found that cattle made more uniform use of vegetation types under rotation than under continuous grazing, but distribution was more influenced by soil series and distance to water under rotation grazing. Stuth et al. (1987) found cattle spent more time grazing preferred sites under rotational than under continuous grazing. Walker et al. (1989) found that cattle were more selective for plant communities under rotation than under continuous grazing, and more selective at the beginning of a rotation grazing period than at the end. They concluded that selectivity declined with decreasing forage and increasing grazing pressure, and grazing system effects were indirect through the impact of systems on grazing pressure.

Grazing time in CL dwindled with distance from water, just as percent use did. Cattle were never observed grazing at the end of

CL farthest from water, although dungpats indicated they sometimes went there. The average of 27% use observed at the far end also indicates some grazing, but some of this might be credited to insects and rodents.

### Cattle Gains

Heavy use of forage near water and little use far from water, plus increased travel time and distance, reduced cow and calf gains on the large continuously grazed pasture (CL). Average daily gains of nursing cows were lower on CL than on the rotation pastures (R) or on the small continuously grazed pastures (CS) in all 5 years studied (Table 4). Only in 1988 were gains of nursing cows less on CS than on R. Calf gains did not differ between R and CS in any year. Calf gains on CL were lower than on CS in all but 1990, and lower than on R in 1986 and 1987.

**Table 4. Gains of nursing and dry cows, calves, and yearling heifers on large and small continuously-grazed and small rotationally grazed pastures.**

| Year | Pasture | Nursing cows | Dry cows | Calves | Heifers |
|---|---|---|---|---|---|
| | | Gain, km/day | | | |
| 1986 | Continuous Large | 0.08 b | 0.46 a | 0.68 b | 0.51 a |
| | Continuous Small | 0.24 a | – | 0.78 a | 0.65 a |
| | Rotation | 0.21 a | 0.51 a | 0.77 a | 0.59 a |
| 1987 | Continuous Large | 0.31 b | 0.69 a | 0.73 b | 0.62 a |
| | Continuous Small | 0.54 a | – | 0.85 a | 0.71 a |
| | Rotation | 0.44 a | 0.71 a | 0.83 a | 0.71 a |
| 1988 | Continuous Large | 0.17 c | 0.66 b | 0.73 b | 0.62 a |
| | Continuous Small | 0.23 b | 0.68 b | 0.95 a | – |
| | Rotation | 0.34 a | 0.73 a | 0.83 ab | 0.74 a |
| 1989 | Continuous Large | 0.23 b | – | 0.83 b | 0.79 a |
| | Continuous Small | 0.42 a | – | 1.06 a | 0.94 a |
| | Rotation | 0.49 a | 0.58 | 0.94 ab | 0.76 a |
| 1990 | Continuous Large | 0.42 b | 0.85 a | 0.89 a | 0.74 b |
| | Continuous Small | 0.61 a | 0.79 a | 0.97 a | 0.78 ab |
| | Rotation | 0.61 a | 0.84 a | 0.94 a | 0.87 a |
| Mean | Continuous Large | 0.24 b | 0.66 a[1] | 0.77 b | 0.66 a |
| | Continuous Small | 0.41 a | – | 0.92 a | – |
| | Rotation | 0.42 a | 0.70 a | 0.86 a | 0.73 a |

a,b Gains of the same class of cattle in the same year, followed by different letters, are different ($P \leq 0.05$).
[1]Mean gains of dry cows exclude 1989 when no dry cows gazed the large continuous pasture.

Reducing pasture size from 207 to 24 ha usually produced marked improvements in cow and calf gains, regardless of grazing system. On 24-ha pastures, grazing system seldom affected cow or calf gains. Cow and calf gains may increase under rotation grazing systems, but because of reduced pasture size, resulting in reduced distance travelled and more uniform grazing, not because of rotation *per se*.

Cows on CL travelled about 2.9 km/day farther than cows on CS and 1.9 kg farther than cows on R (Table 3). Hepworth et al. (1991), using data of Brody (1945) and Clapperton (1964), calculated an energy requirement of 51 kilocalories/km of travel/100 kg of body weight. Ribiero et al. (1977) calculated 48 kilocalories/km of travel/100 kg of body weight. Average weight of cows observed in the current study was about 500 kg. At an energy requirement of 4,200 kilocalories/kg of gain (Garrett et al. 1959) and 50 kilocalories/km of travel/100 kg of body weight, CL cows should have gained 0.17 kg/day less than CS and 0.11 kg less than R cows. The observed differences in average daily gain were similar, 0.17 kg less than CS (0.24 vs. 0.41 kg) and 0.18 kg less than R (0.24 vs 0.42 kg; Table 4).

Gains of heifers and dry cows showed little response to grazing system or pasture size. Heifer gains in 1990 were lower on CL than on R. No other significant differences in heifer gains were detected among treatments, partly because of the small number of heifers per pasture. Dry cows on CS and CL gained less than those on R in 1988. Pasture size or distance to water made little difference to dry cows; free of maternal responsibilities, they ranged widely.

## Conclusions

Results of this study emphasize the importance of 2 requirements of sound range management, proper stocking rate and even livestock distribution. They also demonstrate that these requirements can be achieved independently of grazing system. Uniformity of grazing use; time spent grazing, resting and traveling; distance travelled by cows; and cattle gains were similar under continuous and time-controlled rotation grazing when pastures on the 2 systems were similar in size, shape, and maximum distance to water. But under continuous grazing with longer maximum distance to water, travel distance increased, grazing (as measured by both utilization and time spent grazing) was much heavier near water than at distances greater than 3 km, and gains of nursing cows and calves decreased. Installation of a rotation grazing system is unlikely to produce higher cattle gains, greater stocking rate, or more uniform grazing unless it is coupled with pasture subdivision and the provision of additional water sources. Subdivision and water may be provided more economically without implementing rotation grazing.

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